

24P

MTP-COMP-64-1  
January 2, 1964

N64-18101  
26  
Cable 1  
mfs

**GEORGE C. MARSHALL**

**SPACE  
FLIGHT  
CENTER**

**HUNTSVILLE, ALABAMA**

OTS PRICE

XEROX

\$

2.60

MICROFILM

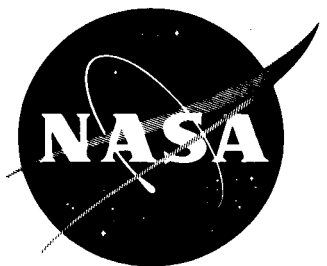
\$

92

SYNTHESIS OF CONTINUOUS ANALOG DATA FROM DISCRETE  
SAMPLE DATA VIA A PB250-TRICE LINK

By

John C. McCoy



FOR INTERNAL USE ONLY

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

GEORGE C. MARSHALL SPACE FLIGHT CENTER

---

MTP-COMP-64-1

---

SYNTHESIS OF CONTINUOUS ANALOG DATA FROM DISCRETE  
SAMPLE DATA VIA A PB250-TRICE LINK

By

John C. McCoy

ABSTRACT

18101

A procedure is described for using discrete, widely dispersed measurements of wind velocity to generate continuous curves suitable for use as driving functions in a simulated flight of the Saturn vehicle. The simulation was already operational on a GPS computer, using synthetic wind functions generated in the computer. Wind functions based on actual measurements at Cape Canaveral are now used.

The observed wind data consist of zonal and meridional velocities measured daily at kilometer intervals above Cape Canaveral, from ground level to 25 kilometers altitude. These data, available in IBM 7090 language, must be converted into continuous analog form.

The problem is solved by first, on the 7090, fitting the 26 values in each set of measurements with a fifth-order smoothing equation. The 7090 next breaks the smoothing curve into 125 segments of equal width, calculates the slopes of straight lines connecting the endpoints of these segments, and records the slopes on tape in PB250 format. With the PB250 acting as interpreter, the TRICE is then used to integrate the slopes with respect to time (the vehicle is assumed to be in vertical flight at constant velocity). Because of the very large number of integration steps per segment, the staircase output of the TRICE approximates a straight line. After digital to analog conversion, zonal and meridional wind profiles in continuous analog form are recorded on magnetic tape for use as inputs to the GPS computer.

*Author*

GEORGE C. MARSHALL SPACE FLIGHT CENTER, *Huntsville, Ala.*  
NASA.

MTP-COMP-64-1

January 2, 1964

t' SYNTHESIS OF CONTINUOUS ANALOG DATA FROM DISCRETE  
SAMPLE DATA VIA A PB250-TRICE LINK

By

John C. McCoy

2 Jan. 1964 24p *info*

(NASA TM X-51542; MTP-COMP-64-1) OTS: B---

FLIGHT SIMULATION BRANCH  
COMPUTATION LABORATORY

## TABLE OF CONTENTS

	Page
SUMMARY	1
SECTION I. INTRODUCTION . . . . .	2
SECTION II. GENERAL DESCRIPTION, SYNTHESIS PROCEDURE . . . . .	3
SECTION III. OPERATION OF THE PB250 . . . . .	11
SECTION IV. OPERATION OF THE BUFFER . . . . .	14
SECTION V. GPS-TRICE TIME SCALING . . . . .	15

## LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	Complete Data Sequence . . . . .	4
2.	TRICE Wind Function Synthesis System . . . . .	5
3.	Data Points and Curve Fitted by 7090 . . . . .	6
4.	Expanded View of Figure 3, Showing 7090 Straight Line Fit . . . . .	7
5.	TRICE Approximation of Straight Line . . . . .	9
6.	Continuous Wind Profile Produced by TRICE System . . . . .	10
7.	PB250 Program (I) . . . . .	12
8.	PB250 Program (II) . . . . .	13
9.	TRICE Program . . . . .	17

GEORGE C. MARSHALL SPACE FLIGHT CENTER

---

MTP-COMP-64-1

---

SYNTHESIS OF CONTINUOUS ANALOG DATA FROM DISCRETE  
SAMPLE DATA VIA A PB250-TRICE LINK

By

John C. McCoy

SUMMARY

A procedure is described for using discrete, widely dispersed measurements of wind velocity to generate continuous curves suitable for use as driving functions in a simulated flight of the Saturn vehicle. The simulation was already operational on a GPS computer, using synthetic wind functions generated in the computer. Wind functions based on actual measurements at Cape Canaveral are now used.

The observed wind data consist of zonal and meridional velocities measured daily at kilometer intervals above Cape Canaveral, from ground level to 25 kilometers altitude. These data, available in IBM 7090 language, must be converted into continuous analog form.

The problem is solved by first, on the 7090, fitting the 26 values in each set of measurements with a fifth-order smoothing equation. The 7090 next breaks the smoothing curve into 125 segments of equal width, calculates the slopes of straight lines connecting the endpoints of these segments, and records the slopes on tape in PB250 format. With the PB250 acting as interpreter, the TRICE is then used to integrate the slopes with respect to time (the vehicle is assumed to be in vertical flight at constant velocity). Because of the very large number of integration steps per segment, the staircase output of the TRICE approximates a straight line. After digital to analog conversion, zonal and meridional wind profiles in continuous analog form are recorded on magnetic tape for use as inputs to the GPS computer.

## SECTION I. INTRODUCTION

This report describes a procedure developed and successfully used by the Flight Simulation Branch to synthesize continuous analog curves from discrete, widely separated sample measurements. Continuous curves representing a 25-kilometer-high wind profile are synthesized, using a TRICE digital differential analyzer, from only 26 measured values.

The Flight Simulation Branch has for some time been using a GPS high-speed repetitive analog computer to conduct statistical studies of the performance of the Saturn vehicle during launch flight (from ground level to 25 kilometers altitude). Ten second-order differential equations describing the behavior of the vehicle are programmed on the computer. Wind velocity as a function of time is the driving function.

In the simulation as originally developed, the wind function was generated electronically by adding a turbulence function to a mean wind function. The mean wind function was generated by a diode function generator and was the same for each of a large number of flights. The turbulence function, filtered to provide the proper frequency content, originated in the GPS noise generator and, because of the random output of the noise generator, was different for each simulated flight. Both the mean wind function and the turbulence filter were selected to simulate as closely as possible an actual wind-versus-altitude profile that might be encountered by the vehicle during launch flight. Wind functions generated in this way were recorded on FM magnetic tape and used to drive the simulation via a reel-to-reel tape recorder synchronized with the operation of the GPS computer.

Questions were raised, however, concerning the realism of electronically generated wind signals. A decision was made to use driving functions based on actual measured winds at Cape Canaveral. These measured winds would serve as the mean wind function--turbulence would continue to be generated as before. Over 10,000 sets of wind velocity observations, taken twice daily since January 1, 1956, were available. The data were directional, in the form of meridional (north-south) and zonal (east-west) components, and they consisted of observations at kilometer intervals from ground level to 25 kilometers altitude.

Continuous curves--one representing the meridional component and one representing the zonal component--had to be synthesized from the 26 pairs of data points in each set of wind observations. The two components of each profile

could then be recorded simultaneously on two channels of magnetic tape and, when used to drive the GPS simulation, they could be added vectorially by the GPS to give the wind profile in the direction of interest. The procedure developed to synthesize these continuous curves will now be described.

## SECTION II. GENERAL DESCRIPTION, SYNTHESIS PROCEDURE

The major part of the synthesis consists of an integration procedure performed by a TRICE digital differential analyzer. Peripheral equipment includes a PB250 general purpose digital computer, a buffer, and two digital-to-analog converters. The entire data processing sequence--from radar observations to simulated flight of the Saturn through the measured winds--is shown on Figure 1. A functional block diagram of the TRICE synthesis system is included as Figure 2.

Initial preparation is on the IBM 7090, since the wind function data already existed in digital form in 7090 language. The 26 data points (velocity at kilometer intervals from ground level to 25 kilometers altitude) in each wind record (one meridional and one zonal) are fitted on the 7090 with a fifth-order smoothing equation ( Fig. 3). The 7090 is then used to break each smoothing curve into 125 segments, the interval between breakpoints being held constant (Fig. 4). Still on the 7090, the slopes of straight lines joining each of the 126 breakpoints are calculated and recorded on digital magnetic tape in a special format readable by the PB250 and suitable to the PB250-TRICE synthesis procedure. Whereas data in 7090 format were paired by component (all meridional values in sequence from ground level to 25 kilometers, then all zonal values), the data in PB250 format are paired by slope (first meridional, first zonal; second meridional, second zonal; etc.). Tagged with an identifying control number, these wind records (slopes) are stored on the tape in chronological order.

The PB250 reads from this tape one wind record at a time, stores the record in its memory, and in response to ready signals from the TRICE, supplies respective pairs of wind slopes to the buffer.

The buffer is the communications link between the PB250 and the TRICE. Loaded by the PB250 with one pair of slopes at a time, the buffer supplies these to the TRICE in response to timing signals from the TRICE. This process continues until a complete wind record has been integrated. The PB250 then reads another record and the process just described is repeated.

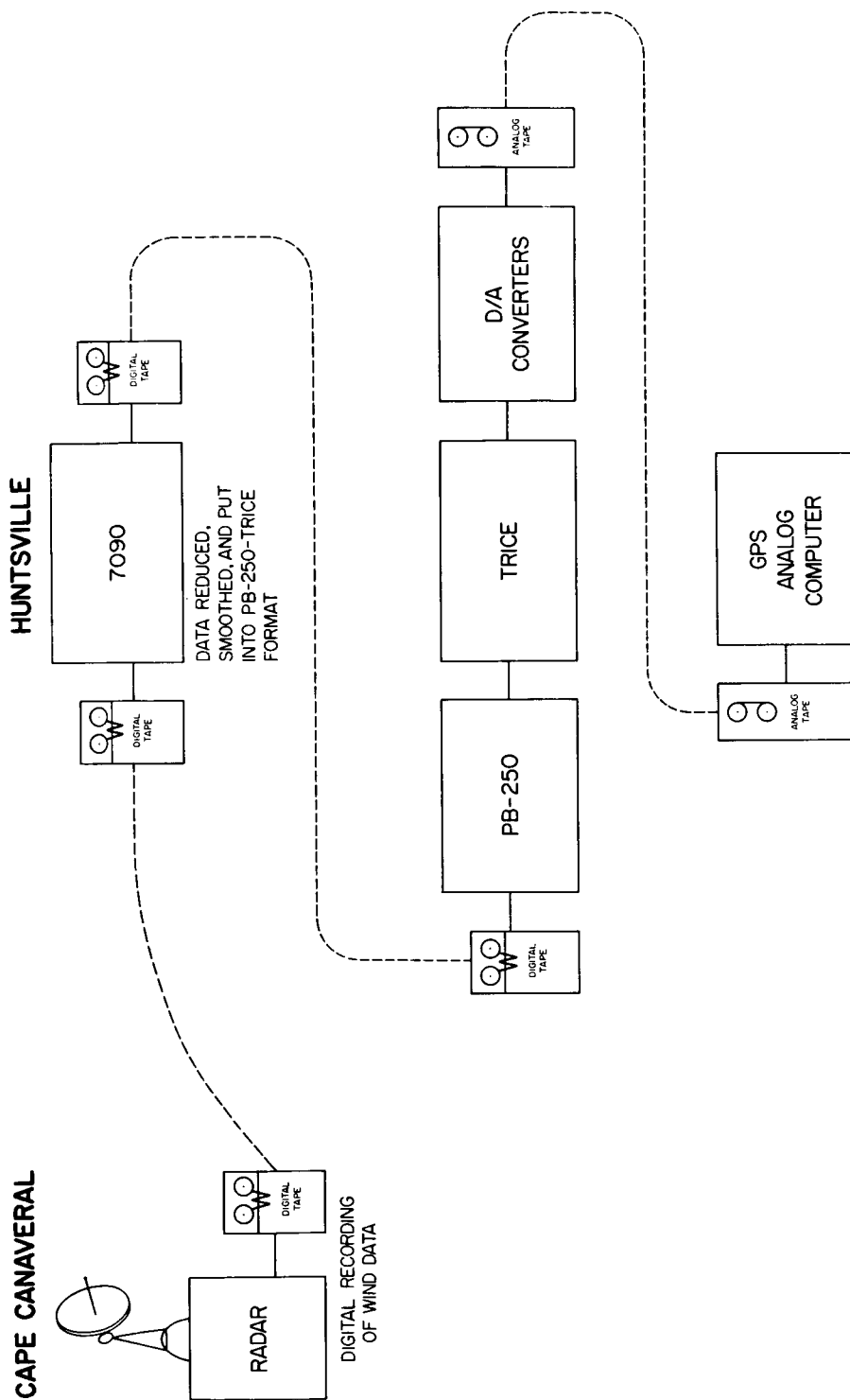


FIGURE 1. COMPLETE DATA SEQUENCE

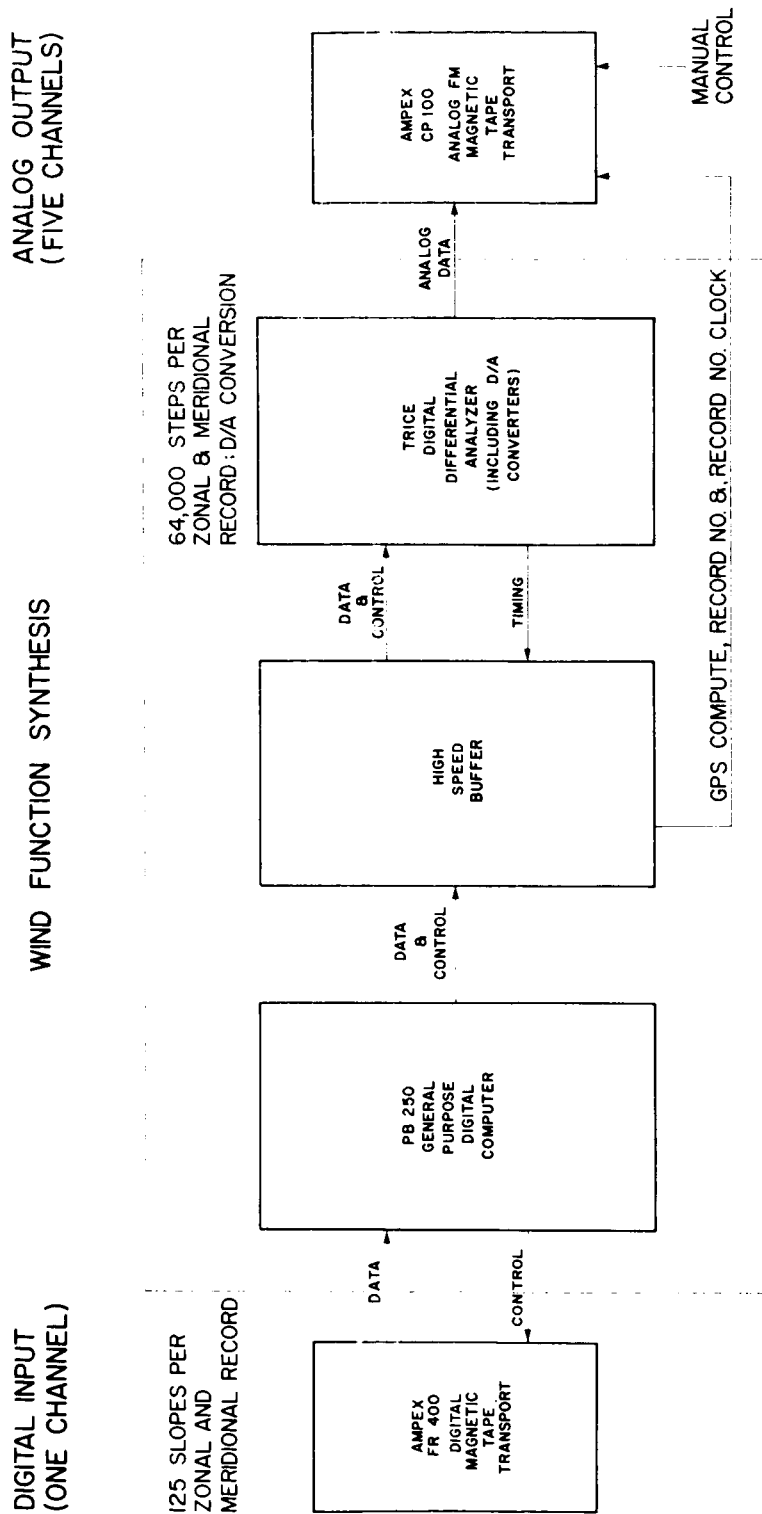


FIGURE 2. TRICE WIND FUNCTION SYNTHESIS SYSTEM

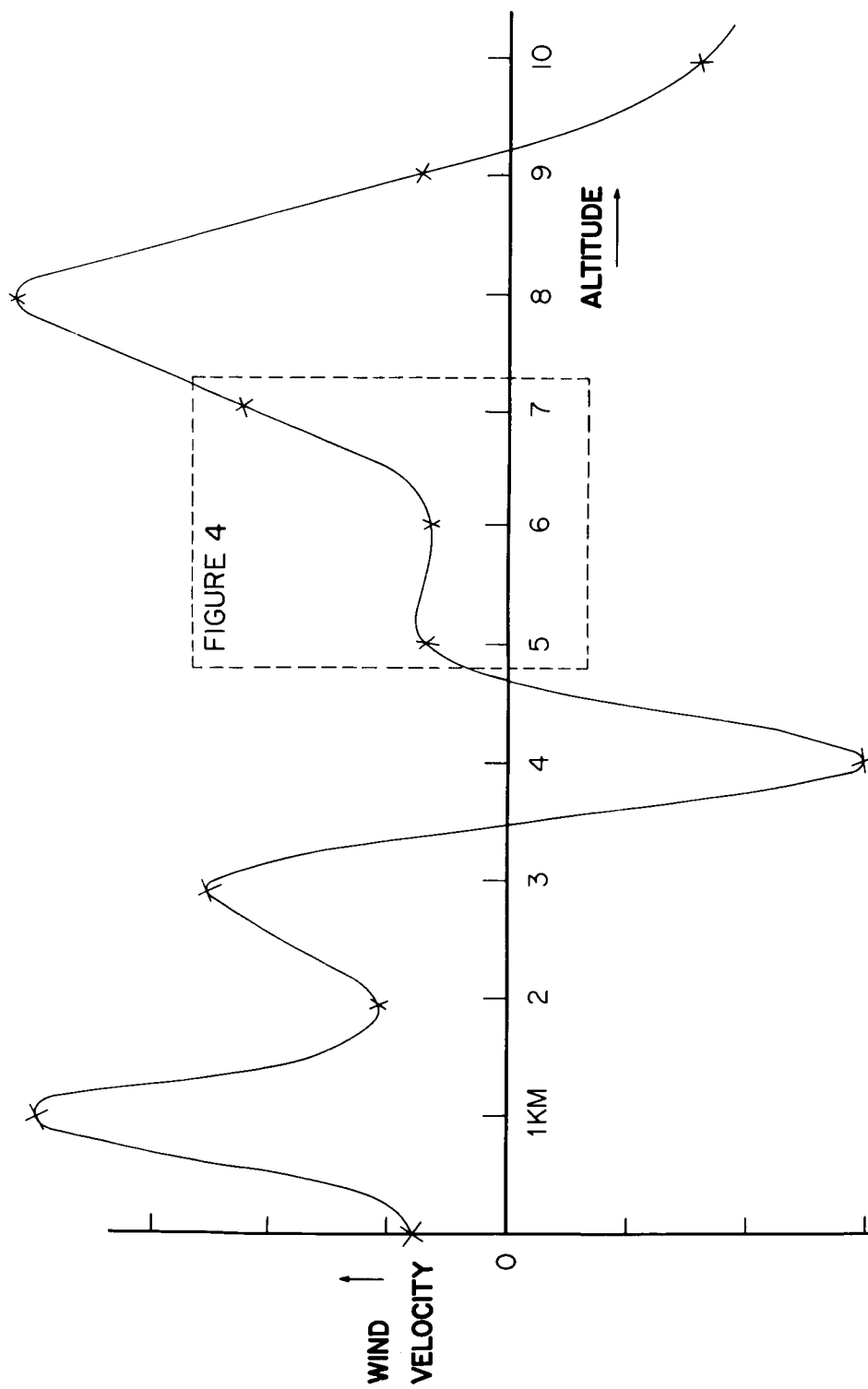


FIGURE 3. DATA POINTS AND CURVE FITTED BY 7090

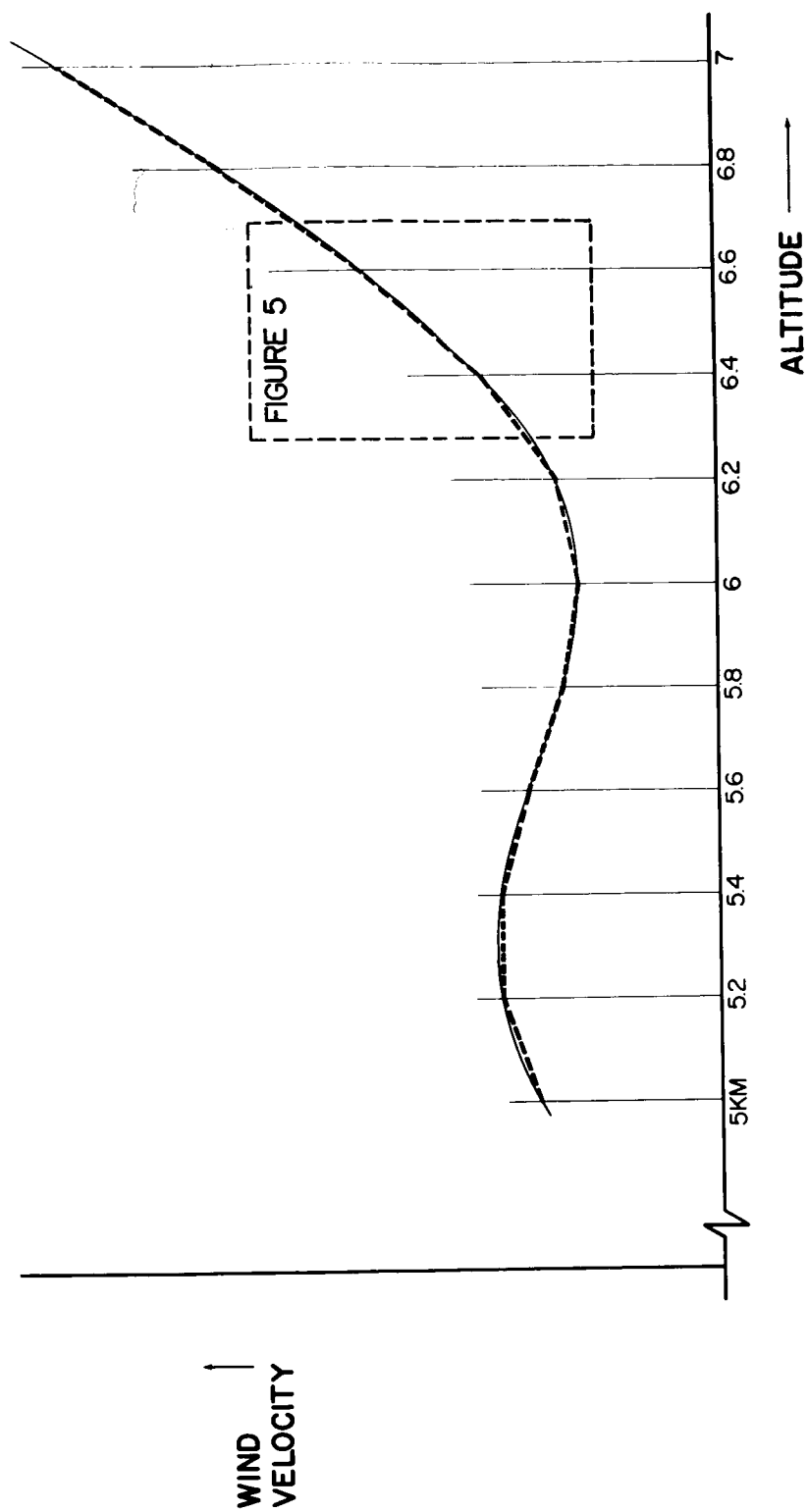


FIGURE 4. EXPANDED VIEW OF FIGURE 3, SHOWING 7090 STRAIGHT LINE FIT

Actual synthesis of continuous curves is performed by the TRICE digital differential analyzer. The 125 pairs of slopes per wind profile are integrated by the TRICE in 512 integration steps per slope, that is, 64,000 steps per component. Thus, while preparation on the 7090 increases the number of data points from 26 to 126 per component, the TRICE raises this number to 64,000--still not a continuous curve, but digital-to-analog conversion is now simple and routine.

Integration in the TRICE is with respect to time. The vehicle is assumed in the GPS simulation to be flying at constant vertical velocity. Thus altitude and time are directly related, and conversion from altitude (in the input data) to time (in the output data) simply involves multiplication by a constant. Two integrators are used so that the meridional slope and the zonal slope in each pair can be integrated simultaneously.

The staircase output of the TRICE, which approximates a continuous curve because of the very large number of integration steps per slope, is illustrated schematically on Figure 5.

Digital-to-analog converters provide the true analog signals that are recorded on two channels of magnetic tape. Three additional channels of the tape are used for control information necessary to the GPS simulation. This information--GPS compute signal, record number, and record number clock--is provided by digital logic under control of the PB250-TRICE (Fig. 2).

Used in completely straightforward fashion, the TRICE has proved highly effective as the key link in the synthesis. Because the TRICE operates by transferring changes in values of the generated variable, rather than the variables themselves, it is able to integrate far more rapidly and economically than a general purpose digital machine. Indeed, because the height of a step in the TRICE staircase output is always a single TRICE secondary increment, it is always below the noise level of the FM tape system that provides input to the GPS computer. Thus the integration steps are imperceptible to the GPS computer.

A continuous wind profile prepared on the TRICE is reproduced as Figure 6.

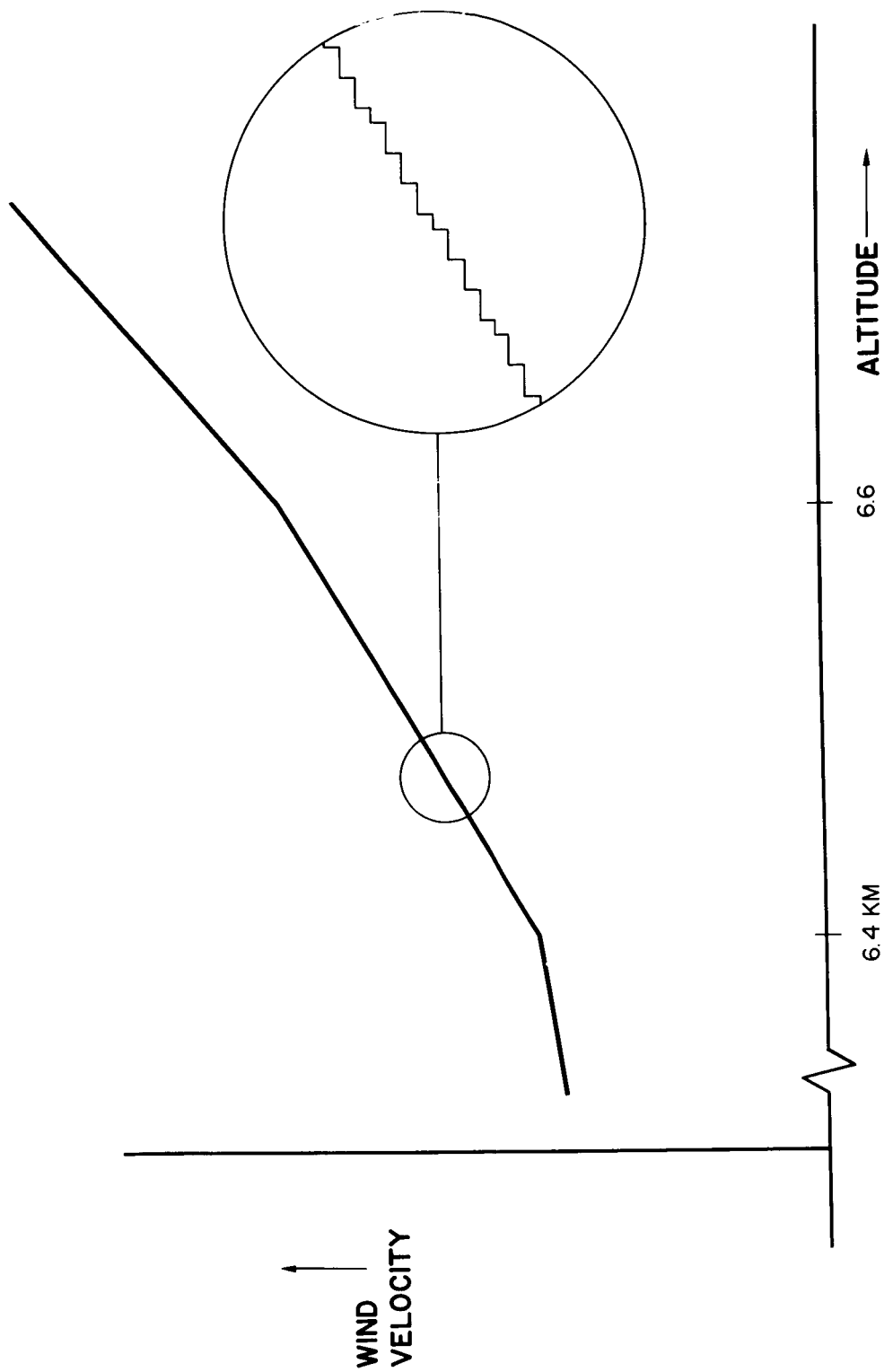


FIGURE 5. TRICE APPROXIMATION OF STRAIGHT LINE

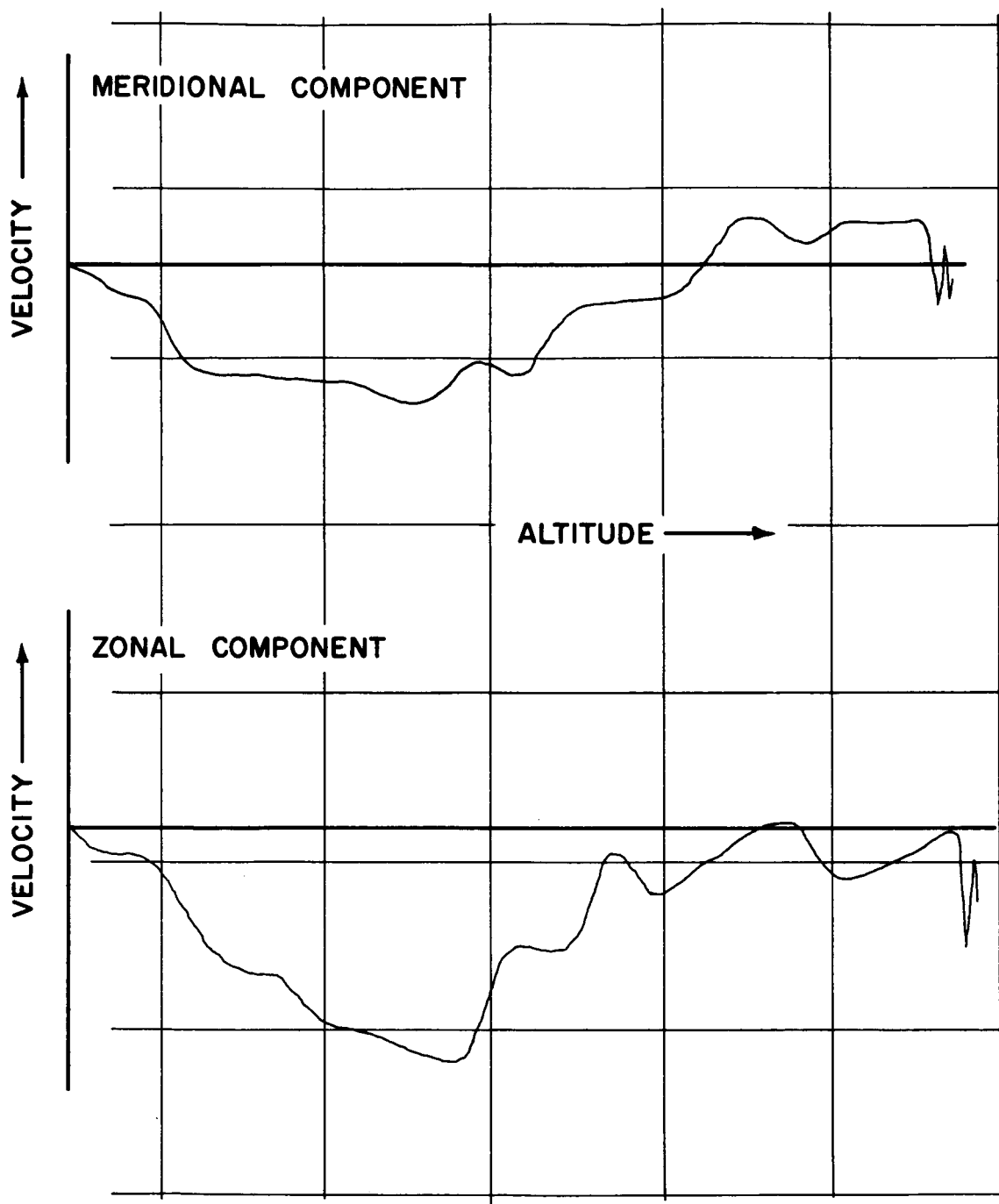


FIGURE 6. CONTINUOUS WIND PROFILE PRODUCED BY TRICE SYSTEM

### SECTION III. OPERATION OF THE PB250

The PB250 computer is a small-size, high-speed digital computer that is fully compatible with the TRICE digital differential analyzer. With input from magnetic tape containing digital wind slope data, the PB250-buffer-TRICE operates as an integrated system to provide continuous analog output on FM magnetic tape. Each magnetic tape contains the twice-daily records of wind slopes for one year, numbered consecutively and recorded in chronological order. The specific contribution by the PB250 is to read one record at a time from the tape input, store the record in its memory, and on command from the TRICE provide one pair of wind slopes at a time to the buffer. Figure 7 is a flow chart showing the record reading and editing routine of the PB250. Figure 8 is a flow chart showing the functional integration of the PB250 into the overall PB250-buffer-TRICE system. A narrative description of the PB250 program follows.

The PB250 program reads from the magnetic tape one wind record at a time. A record consists of 134 data words: the first six are dummy slopes that provide initial conditions, the next 125 are the respective pairs of meridional and zonal slopes, and the remaining three are the record number. Satisfied that a correct read has been obtained, the program stores the record in its memory and sets up an editing procedure based on the record number of this stored record. First, the program checks to determine whether the record is the last of the year (and therefore of the reel). If this condition is satisfied, that is, if the record is the last record of the reel, the program modifies itself to halt. Next, the program checks to determine whether the record is the last record of the month. If this condition is satisfied, that is, if the record is the last record of the month, the program is delayed 150 seconds to allow time and space for identification of the month on the analog output tape.

In any event, the program now loads the buffer with the record number, sets up a breakpoint checking loop for the buffer, and initializes the TRICE. Once initialized, the TRICE is tested to determine whether it is ready to receive data. This test is repeated at 3.072-millisecond intervals until a ready signal is received.

Having received a ready signal from the TRICE, the program processes the data, that is, loads the buffer with the  $i$ -th pair of slopes, signals that the buffer is loaded, and checks the TRICE again to determine whether it is ready to integrate the  $i$ -th pair of slopes (loading, signaling, and checking are performed within 6.144 milliseconds). This procedure is repeated until all 134 data words in a record have been loaded into the buffer. After a record has been processed in this way, the program reads a new record from the magnetic tape, and repeats the foregoing procedure until a year's wind data have been processed.

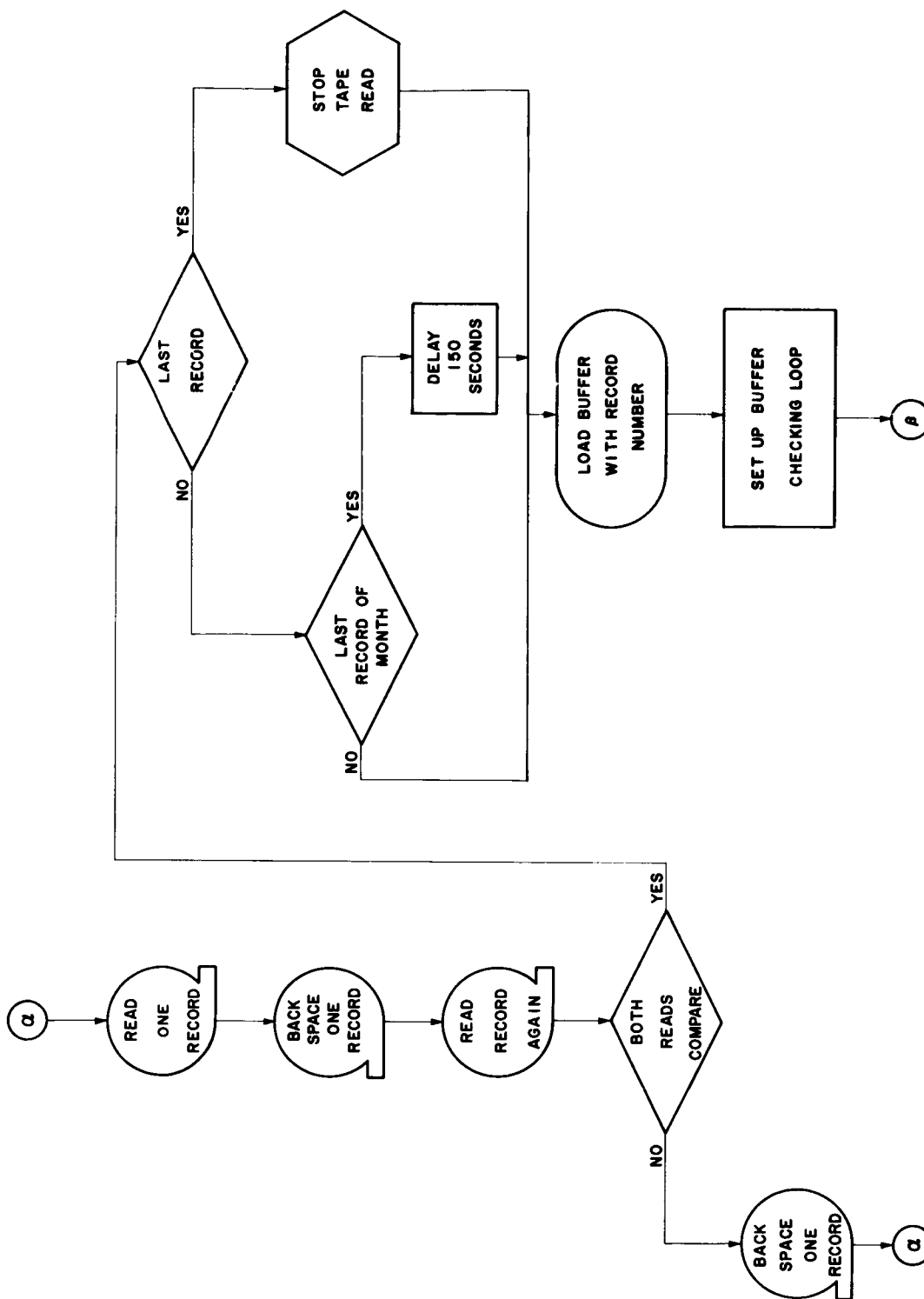


FIGURE 7. PB250 PROGRAM (I)

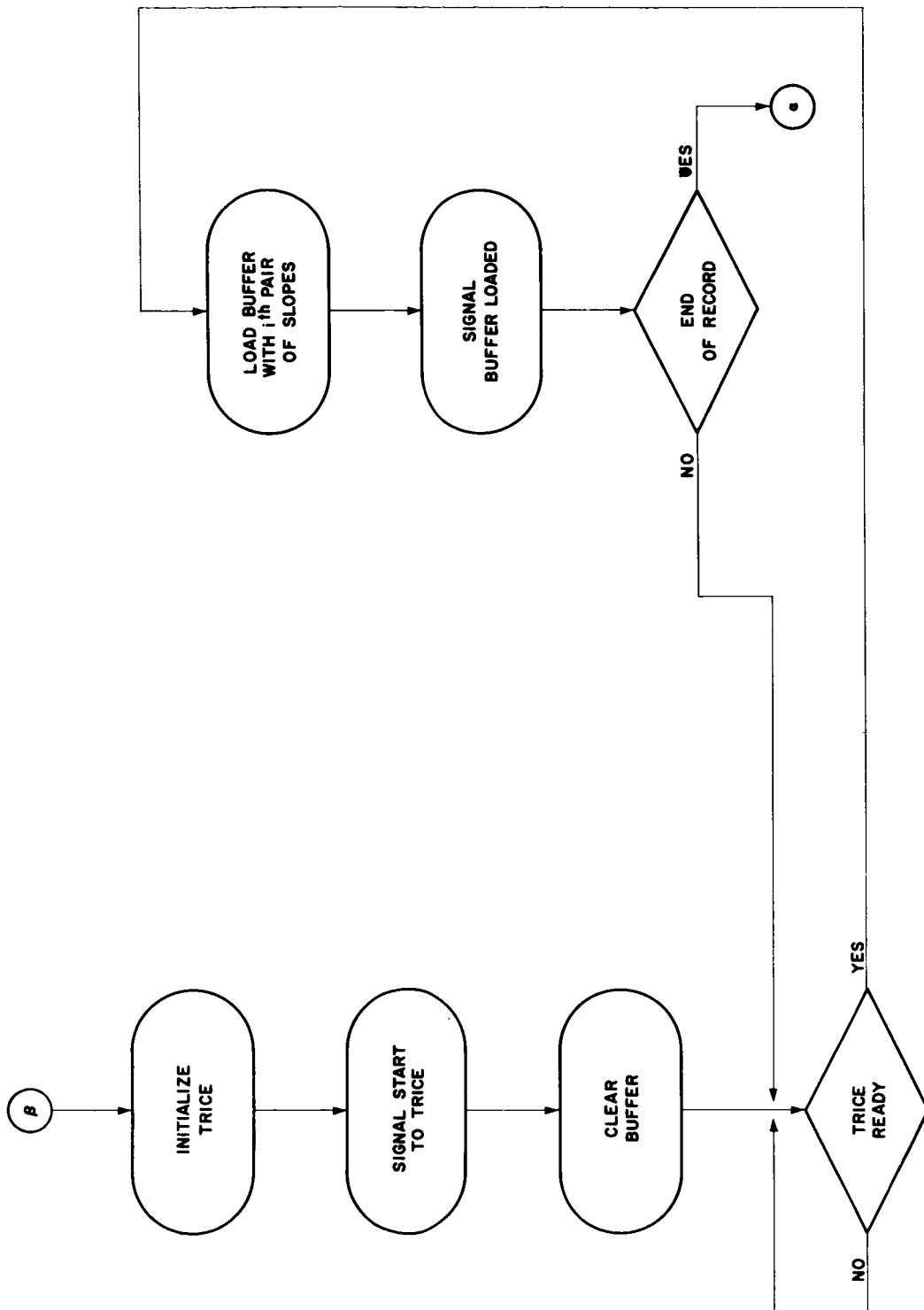


FIGURE 8. PB250 PROGRAM (II)

#### SECTION IV. OPERATION OF THE BUFFER

A buffer is used between the PB250 general purpose digital computer and the TRICE digital differential analyzer. The buffer is the communications link between the two machines, which operate asynchronously. In addition, for reasons of convenience, the buffer houses the circuitry used to shape or generate the control signals recorded on the analog tape output of the TRICE. These are the record number, the record number clock, and a compute or operate pulse ("GPS Compute") for the GPS computer.

The capacity of the buffer, which utilizes shift register techniques, is 30 bits. The slope data are received from the PB250 in two-word groups at a bit shift rate of 2 microseconds. One word group bears the meridional wind data; the other group bears the zonal wind data. Each word is shifted into the buffer so that it occupies 15 bit positions. Thus, with both word groups loaded into the buffer, the full 30-bit capacity of the buffer is utilized.

Each word group consists of a sign bit, ten data bits, and four dummy bits, which are included to allow for handling more accurate data in the future without major hardware changes. It should be mentioned, however, that the one's complement configuration is used for negative numbers in the current program. Thus the dummy bits are ones for all negative data words and the sign bit position is tested for a negative sign before each data word is loaded into the TRICE. If it tests true, indicating a negative sign, the dummy bits are loaded into the TRICE as ones.

After "TRICE Compute" is initialized by the PB250, the TRICE provides the breakpoint checking signal to the buffer, and also the control signal that indicates to the buffer that an analog record is complete (131 slopes integrated). A third signal from the TRICE to the buffer, delayed 451 milliseconds (as explained in Section V. GPS-TRICE Time Scaling) after the initializing of "TRICE Compute," turns "on" the "GPS Compute" signal recorded FM on a third channel of the magnetic tape output of the TRICE. (The first and second channels contain, respectively, FM records of the meridional and zonal wind functions.)

Finally, under control of the PB250, the buffer performs one additional function. It records an identifying record number and record number clock on a fourth and fifth channel, respectively, of the TRICE output tape before each analog record (continuous wind profile) is recorded. The record number is loaded into the buffer in the same way as are the data work groups. But each bit

of the record number is read out in digital fashion and is recorded on a direct record channel of the analog recorder. Timing of the readout is controlled by the PB250. The record number clock is also recorded on a direct record channel of the analog tape.

## SECTION V. GPS-TRICE TIME SCALING

The basic Saturn launch simulation on the GPS computer includes, as a given, a simulated constant vehicle ascent velocity of 500 meters per second.<sup>1</sup> At this velocity, the distance from ground to 25 kilometers altitude would be traversed in 50 seconds of real time. To increase the effective bandwidth of the computer and therefore the precision of the simulation, the GPS is run at one-eighth its normal speed of 3014 times real time. Thus the GPS time scale is  $\frac{3014}{8} = 376.75$  times real time, and GPS machine time for one flight is

$$\frac{50 \text{ sec} \times 8}{3014} = 132 \text{ milliseconds.}$$

Each wind driving function must of course run for precisely this time. But the optimum TRICE machine time to produce a wind signal (to integrate the 125 pairs of slopes representing the wind function) is considerably longer than 132 milliseconds. The wind signals (functions) originating in the TRICE are therefore recorded on magnetic tape moving at a slow speed and played at a higher speed to drive the GPS simulation. A convenient ratio of tape drive speeds that will allow the TRICE to operate at an optimum speed is 32. The wind function is recorded on magnetic tape moving at  $1\frac{7}{8}$  inches per second and played into the GPS at 60 inches per second. Clearly, then, TRICE time to compute one wind function is 4.23 seconds ( $32 / 0.132 \text{ sec} = 4.23 \text{ sec}$ ).

---

<sup>1</sup>The simulated ascent velocity can, in fact, be varied according to the requirements of the problem being studied on the GPS. But identical scaling of the GPS and the TRICE system used to prepare the wind driving functions must be based on the same (i. e., a single) real time ascent velocity.

TRICE machine time must now be related to problem time (Fig. 9).

$$\frac{\text{Problem time (real, flight time)}}{\text{Machine time (TRICE time)}} = \frac{50 \text{ sec}}{4.23 \text{ sec}} = 11.8$$

Constant Multiplier (CM) 1, shown on Figure 9, establishes problem time by multiplying TRICE machine time by 11.8.

Signals to the buffer telling it that a breakpoint has been passed (one pair of slopes has been integrated and another pair is needed) originate in CM 2 (Fig. 9). Because each continuous wind function is generated from input to the TRICE consisting of 125 slopes and because each wind function occurs in 50 seconds of real time, a breakpoint is passed and a signal is sent to the buffer every  $\frac{50 \text{ sec}}{125} = 0.4$  second of real time.

CM 3 (Fig. 9) counts these breakpoints and causes Integrator 1 (Fig. 9) to overflow when the full number of breakpoints for one complete wind function has been accumulated. Overflow of Integrator 1 halts the TRICE, which in turn must be restarted by the PB250 to begin integration of the next wind profile after the proper delay.

As will be shown, the "full number of breakpoints for one wind function" is not 126, as might be expected, but 134. Time must be allowed between wind function records (there must be an interval on the magnetic tape) for necessary machine functions preparatory to processing a new wind function: There must be a delay while the PB250 reads a new record, and during this delay the GPS must be reset. The precise time of the delay allotted for completion of these functions is not important, so long as it is sufficiently long for them to be completed, and need not be discussed further.

After the delay allowing the PB250 to read a new record and allowing the GPS to be reset, there is another, shorter preparatory delay that begins at the beginning of the TRICE computation cycle. The precise time of this delay is important and should be discussed. It lasts for 1.155 seconds of problem time and events during the interval are broken down as follows: First, in terms of breakpoints in the TRICE computation cycle, the interval lasts for nine breakpoints (the additional nine making a total of 134). Three of these allow for moving the first pair of slopes from the buffer through the TRICE I (initial condition) register to the TRICE Y register. The other six of these are dummy pairs of slopes providing initial conditions so that the GPS can start computation with the proper simulated initial velocity.

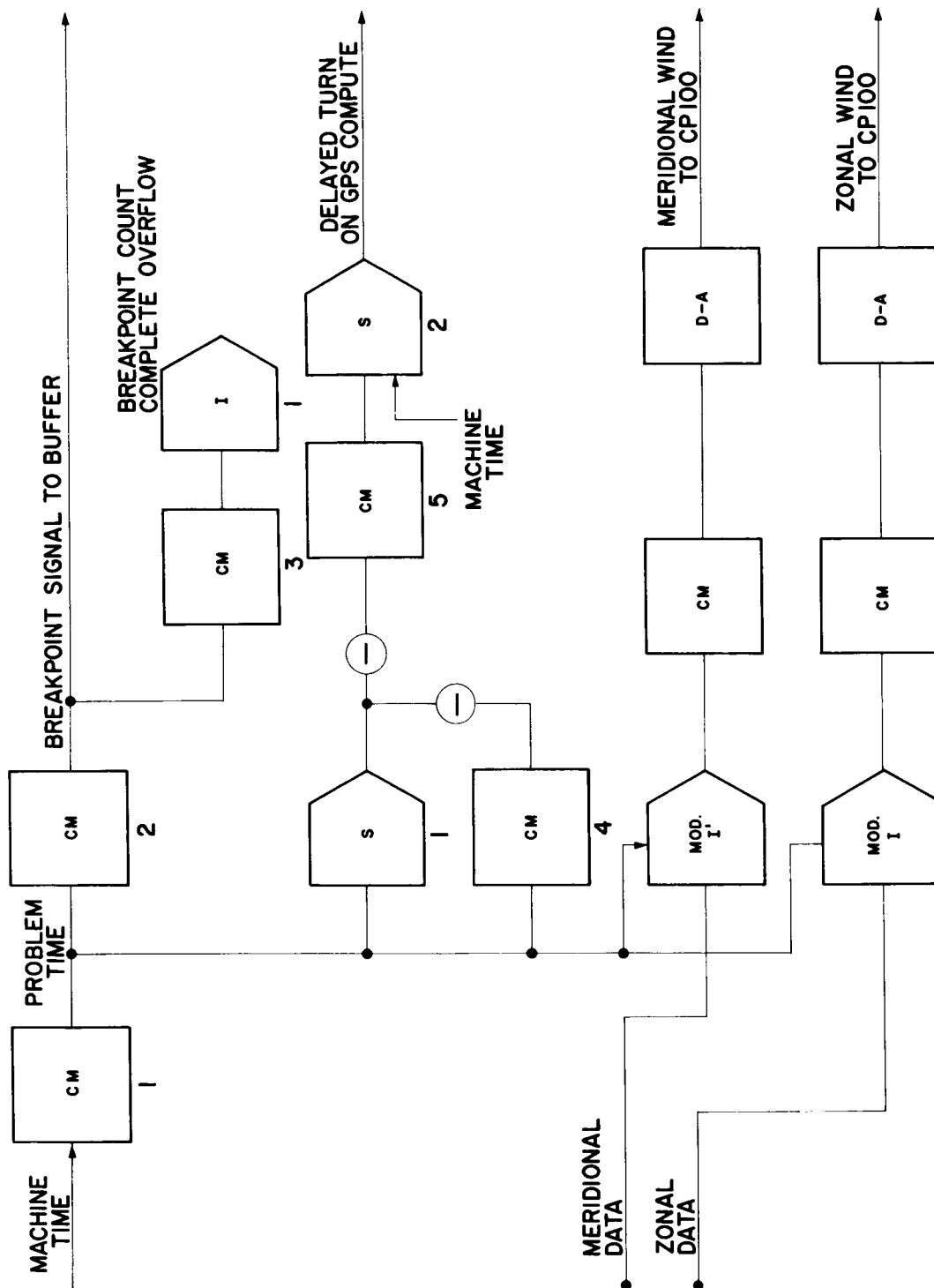


FIGURE 9. TRICE PROGRAM

Second, at some instant during this interval, the "GPS Compute" signal is given by the TRICE and recorded on the third channel of the output tape. Because there is a lag between the time this signal is given and the time GPS computation actually begins, the signal must be given in advance of the time GPS computation must begin (i. e. , in advance of the complete integration of all six dummy slopes by the TRICE and the consequent establishment of the initial simulated velocity in the GPS). That advance time was determined to be 0.704 second of problem time. Or the "GPS Compute" signal is turned "on" 0.451 second after the TRICE computation cycle begins ( $1.55 \text{ sec} - 0.704 \text{ sec} = 0.451 \text{ sec}$ ). A servo countdown loop (S 1, CM 4, CM 5, and S 2 on Fig. 9) provides for this 0.451-second delay in giving the "GPS Compute" signal.

Once generation of an analog wind record begins, the TRICE, to provide an accurate, continuous, and smooth analog representation of the wind data, must compute continuously or must at least be in the compute mode for a very large percentage of operating time. To fulfill this requirement, the two integrators used to integrate the slopes were modified so that the  $(i + 1)$  data for each can be loaded into the I (initial condition) register of the TRICE while the rest of the integrator unit is performing an incremental multiplication using  $i$ -th data. When the  $(i + 1)$  breakpoint is generated, all the  $(i + 1)$  data in the I register are loaded into the Y register in 10 microseconds of real time. Thus non-compute time is insignificant.

APPROVAL

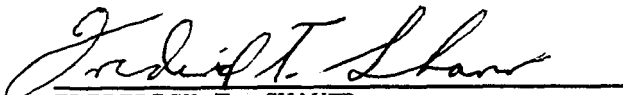
MTP-COMP-64-1

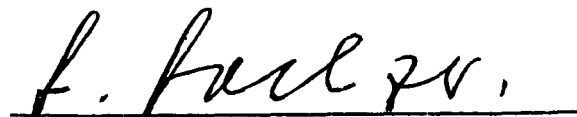
SYNTHESIS OF CONTINUOUS ANALOG DATA FROM DISCRETE  
SAMPLE DATA VIA A PB250-TRICE LINK

By

John C. McCoy

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

  
FREDERICK T. SHAVER  
Chief, Simulation Branch

  
H. HOELZER  
Director, Computation Laboratory

## DISTRIBUTION

### INTERNAL

DIR  
DEP-T  
AST-S

R-DIR

R-AERO-DIR  
R-AERO-S  
R-AERO-A  
R-AERO-AD  
R-AERO-AE  
R-AERO-G  
R-AERO-GA  
R-AERO-GM  
R-AERO-GG  
R-AERO-E  
R-AERO-EE  
R-AERO-EM  
R-AERO-EG  
R-AERO-M  
R-AERO-MS  
R-AERO-MM  
R-AERO-MA  
R-AERO-P

MS-IP  
MS-IPL (8)

FIN

LVO-DIR

I-MICH-OA

R-ASTR-DIR  
R-ASTR-T  
R-ASTR-N  
R-ASTR-NE  
R-ASTR-NV  
R-ASTR-G  
R-ASTR-GC  
R-ASTR-GD  
R-ASTR-GA  
R-ASTR-W  
R-ASTR-WC  
R-ASTR-WS  
R-ASTR-I  
R-ASTR-IM  
R-ASTR-IS  
R-ASTR-IT  
R-ASTR-R  
R-ASTR-T  
R-ASTR-D

R-COMP-DIR (3)  
R-COMP-T  
R-COMP-R  
R-COMP-RR  
R-COMP-RD  
R-COMP-RS (20)

R-ME-DIR

R-RP-DIR

R-QUAL-DIR

R-TEST-DIR

## DISTRIBUTION (Concluded)

### INTERNAL (Concluded)

I-I/IB-DIR

I-V-DIR

I-MICH

R-P&VE-DIR

R-P&VE-P

R-P&VE-M

R-P&VE-MC

R-P&VE-PA

R-P&VE-PM

R-P&VE-PP

R-P&VE-PE

R-P&VE-S

R-P&VE-SA

R-P&VE-SL

R-P&VE-SE

R-P&VE-SV

R-P&VE-D

R-P&VE-DD

R-P&VE-DI

R-P&VE-DA

R-P&VE-DV

HMEP

CC-P

MS-H

### EXTERNAL

Scientific and Technical Information Facility (2)

Attn: NASA Representative (S-AK/RKT)

P. O. Box 5700

Bethesda, Maryland